UNIVERSITY OF PENNSYLVANIA

SERIAL LEARNING AND GENERALIZING ABSTRACTION

LEON ARONS

A THESIS

IN PSYCHOLOGY

PRESENTED TO THE FACULTY OF THE GRADUATE SCHOOL IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

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SERIAL LEARNING AND GENERALIZING ABSTRACTION

By LEON ARONS, University of Pennsylvania

While there have been a number of investigations of the higher mental processes,[1] little has been done specifically comparing (in quantitative terms) serial learning of the language type with generalizing abstraction. "The establishment of mere *chains* of verbal reflexes as in the learning of a string of nonsense syllables is one type of linguistic organization."[2] On the other hand, generalizing abstraction as a function of "symbolic intelligence," might be expected, to an extent, to be dependent upon degree of facility at acquiring these "mere chains of verbal reflexes." Briefly, our problem is to investigate the degree of correlation between an *S*'s ability at serial learning with his ability at generalizing abstraction as revealed by the "multiple choice" method.

METHOD AND PROCEDURE

Most investigations of learning (verbal) have made use of nonsense material. The comparative degree of nonsense of this material may be questioned.[3] In addition, for our purpose, it is most desirable to use a method which will give a wide range and distribution of scores. We have therefore chosen material (playing cards) which is relatively meaningless, and have placed the emphasis on acquisition in pattern (serial) form. Differences in 'card background' are minimally significant. All *S*s may be expected to know the names of the cards. This method will also give us our desired scatter of scores.[4]

There is a paucity of experimental data on generalizing abstraction. Moreover, the term itself is somewhat vague, or at least, too general in its connotation. The latter is especially true if we are to consider generalizing abstraction to be synonymous with concept, as Hull seems to do,[5] although at times he uses the term "general-

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I wish to express my indebtedness to the many *S*s who served in this investigation, and to Professor Samuel W. Fernberger and Dr. Francis W. Irwin who offered invaluable criticism and advice.

[1] J. C. Peterson, Higher mental processes in learning, *Psychol. Monog.*, 28, 1920 (no. 129), 1-127; B. F. Haught, Interrelation of some higher learning processes, *ibid.*, 30, 1922 (no. 139), 1-71. For other references see these two studies.

[2] F. Lorimer, *The Growth of Reason*, 1929, 93.

[3] F. C. Davis, The relative reliability of words and nonsense syllables as learning material, *J. Exper. Psychol.*, 13, 1930, 221-234; F. M. Sauer, The relative variability of nonsense syllables and words, *ibid.*, 13, 1930, 235-246.

[4] Our method is similar to Renshaw's (cf. S. Renshaw, Experiment of the learning of 'paried associates,' *J. Appl. Psychol.*, 11, 1927, 226-233).

[5] C. L. Hull, Quantitative aspects of the evolution of concepts, *Psychol. Monog.*, 28, 1920, (no. 123), 1-85. For criticisms of methods used by Grünbaum, Moore, and Fisher, see Hull; for more recent references, see N. H. F. Maier, Reasoning in humans, *J. Comp. Psychol.*, 10, 1930, 115-144.

izing abstraction" interchangeably with "methods by which concepts are evolved." He lists three types: (1) a type exemplified by a child withdrawing from an electric glowing bulb after having been burned by a candle; (2) a type of "generalizing abstraction is involved in the so-called inductive 'steps' of formal instruction originated by Herbart," which he thinks "has strong elements of artificiality," and (3) the "standard" type, which he believes to be the method by which the great majority of actual concepts are evolved. In this latter type, the "formation of the concepts has never been an end deliberately sought for itself . . . always a means to an end—the supremely absorbing task of physical and social reaction and adjustment."[6]

We chose, secondly, the Yerkes multiple choice method,[7] which presents a number of novel settings (situations). One 'key' in each set will sound a buzzer. *S* collects his data (observations) so as to be able to formulate a rule (generalization) which will enable him to predict the buzzer key for any other setting given him. In other words, when the *S*'s behavior becomes 'adequately' generalized with respect to these situations (with the concomitant language 'key'), he is considered to have solved the problem.

Technique. (A) Serial learning. S, seated at a small table in a quiet room, with *E* opposite, was given a deck of playing cards (previously arranged) face down, and the following instructions.

Here is an ordinary deck of playing cards. You are to learn as many as possible in correct order. Here is how you are to go about it. When you are ready to start, hold the deck face up in the palm of your hand. Call out the top card, the name and the suite, then put it face down on the table in front of you. Then call out the card now on top, and put it face down on the first card. In this manner go through the entire deck. When you have finished going through the deck, I shall ask you to call off as many cards in correct order (starting from the first), as you can. Having recited, you will go through the deck again, and so on. After each leafing of the deck you recite. You have 15 min. to spend in actually going through the deck. Within the limits given by these directions, you can go about it in any manner you choose, as rapidly or slowly as you like, and so on. Don't cram, but go about it as efficiently as possible. Try to work out an optimum method for yourself of going about it. You are not to look back once you have put a card down, and you are to uncover but one card at a time. These cards are not arranged according to any key, so do not waste any time looking for one. Remember as many cards as possible, in correct order starting from the first.

At the end of the first "card period," the *S*'s method of going about the learning was discussed with him, and he was allowed to formulate what he considered the best way of going about it the next time. He was told that a different order of cards would be used the second time, and was asked not to practice in the interim.

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[6] It might be well for us to indicate what we mean by "generalizing abstraction." We would inscribe the highly popular adjective 'dynamic' into the matter, and consider generalizing abstraction as generalized behavior with a language (in the broadest sense) 'key' or 'tab.' In no sense do we intend to suggest a dichotomy between the 'behavior' and the 'key,' nor to reify either term. Behavior is 'generalized' with respect to certain situations. An aspect of the generalizing is the language 'key.' The key may be considered a formula of the whole of this behavior in symbolic terms.

[7] R. M. Yerkes, A new method for studying the ideational behavior of mentally defective and deranged as compared with normal individuals, *J. Comp. Psychol.,* 1, 1921, 369-394.

Time for each leafing of the deck was recorded (stop watch) along with the *S*'s recitations. When the remainder of the time prescribed permitted of but one leafing more, *S* was notified of the fact. The 15-min. periods were kept within 30-sec. limits. Two card periods were used, separated by approximately 48 hr. At the second period *S* was told to go about it on the basis of experience acquired the first time, otherwise the directions were the same. *S* was asked to describe his method of learning after each period.

The order of cards for each period was as follows.

Period 1. 3H, 7D, AH, 8C, KS, 10H, JC, 3S, 5D, 2C, 8D, 10S, 4H, KC, 7C, 4D, 9H, QC, 6D, AS, JD, 4S, 8H, QS, 6C, JS, KH, 3D, 5S, AC, 9S, JH, 4C, 2D, 9C, 7H, 10D, 5C, 2H, 8S, KD, 7C, 9D, 2S, QD, 5H, 10C, 6H, AD, QH, 3C, 6S.

Period 2. 9C, 5D, JS, 3C, AD, 5H, QS, 9D, 8C, 6D, 9H, AC, 6C, KH, 10S, 3D, 7H, 5C, JD, 2C, 8D, 4S, KD, AH, 8H, QH, 6H, QC, 2D, 4C, KS, 8S, 7C, 3S, 6S, KC, AS, 4D, 10H, 2S, 9S, 2H, 5S, 10C, 4H, JH, 7S, 10D, 3H, QD, JC, 7D.

(B) Multiple choice. The Yerkes multiple choice apparatus was used in this part of the experiment. The problems may be said to differ in two ways: (1) according to principle involved; and (2) according to point of reference or application. Such principles as middleness, alternation, number of groups, odd-and-evenness, etc. may be used, and such points of reference, which are more limited, as the ends, the center, etc. In our choice of problems we endeavored to make use of a different principle in every problem, and to avoid the mere complication of principles already given the *S*. Points of reference also were kept simple. We may, therefore, expect results which will give a fairly accurate 'picture' of the *S;* chance factors in the solution having been reduced to a minimum.

The principles made use of in these problems are not new to *S*. In his background will be found such abstractions as middleness, spacial progression, and the like. He must, however, arrive at a generalization adequate to the problem in hand. Here the matter of 'direction' of activities, relational discriminations, and so on, are involved.[8] The verbal generalization finally evolved is a product of these situations, and is an aspect of *S*'s 'generalizing behavior.' A list of the 6 problems used is given in Table I.[9] The explanatory portion following the problem number gives a statement of the solution. The settings are given in their order of presentation to the *S:* "1–7" indicates that keys one to seven inclusive were extended in this particular setting. The parenthetical number designates the correct key for this setting. Two series of numbers for correct keys will be found for Problem V. This problem is one of alternation, and inasmuch as there is an odd number of sets, repetition of sets after the 15 listed sets have been used, will bring about a shift in the keys correct for the next 15 sets. The correct keys for these sets (sets 16 to 30) will be found in the second column of parenthetical numbers. It should be stated that the series of sets listed were repeated. The maximum number of sets allowed will be discussed in a later section. The order of presentation of the problems is based upon a preliminary investigation on 20 *S*s. In this present investigation, the order of presentation was Problems I, III, II, IV, V, and VI.

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[8] Cf. Maier, *op. cit.*

[9] Four of our problems were used by Yerkes: Problem 1—Yerkes No. 3; Problem II—Yerkes No. 6; Problem III—Yerkes No. 1; and Problem V—Yerkes No. 10.

TABLE I

THE MULTIPLE CHOICE PROBLEMS AND THEIR SOLUTIONS
(Figures in parentheses give correct key)

Problem I. Principle involved: middle key.

1.	1–7	(4)	3. 6–10	(8)	6. 4–10	(7)	9. 1–5	(3)
2.	10–12	(11)	4. 1–11	(6)	7. 1–9	(5)	10. 6–12	(9)
			5. 1–3	(2)	8. 9–11	(10)		

Problem II. Principle involved: starting with key 12, the next key to left at every trial.

1.	10–12	(12)	4. 8–12	(9)	7. 5–8	(6)	10. 3–7	(3)
2.	6–12	(11)	5. 8–10	(8)	8. 4–9	(5)	11. 1–5	(2)
3.	3–10	(10)	6. 1–9	(7)	9. 2–11	(4)	12. 1–12	(1)

Problem III. Principle involved: same key at every trial, *i.e.* no. 5 from left.

1.	1–6	(5)	3. 4–6	(5)	6. 4–5	(5)	9. 1–8	(5)
2.	3–12	(5)	4. 5–9	(5)	7. 4–10	(5)	10. 5–10	(5)
			5. 2–10	(5)	8. 3–6	(5)		

Problem IV. Principle involved: first key from right with even number of keys, and second key from right with odd number of keys.

1.	1–5	(4)	5. 4–7; 9–12	(12)	9. 3–12	(12)	13. 7–9	(8)
2.	3–8	(8)	6. 1–11	(10)	10. 1–3; 7; 9–11	(10)	14. 2–11	(11)
3.	5–6	(6)	7. 4–6	(5)	11. 2–9	(9)	15. 6–12	(11)
4.	8–12	(11)	8. 8–11	(11)	12. 6–7; 9–11	(10)		

Problem V. Principle involved: alternately the key to the left and right of the middle key.

1.	1–7	(3)	(5)	6.	3–9	(7)	(5)	11.	4–12	(7)	(9)
2.	8–12	(11)	(9)	7.	2–4	(2)	(4)	12.	3–5	(5)	(3)
3.	2–10	(5)	(7)	8.	6–10	(9)	(7)	13.	4–10	(6)	(8)
4.	10–12	(12)	(10)	9.	6–12	(8)	(10)	14.	5–9	(8)	(6)
5.	1–9	(4)	(6)	10.	3–7	(6)	(4)	15.	2–12	(6)	(8)

Problem VI. Principle involved: as many keys from the left as there are groups extended.

1.	1–6; 10–12	(2)	6.	3–10	(3)	11.	5–9; 12	(6)
2.	1; 7; 9; 12	(12)	7.	1; 5; 8	(8)	12.	2; 4–6; 8; 10; 12	(8)
3.	4–12	(4)	8.	1–3; 6–8; 10; 12	(6)	13.	1–5; 7; 11–12	(3)
4.	4–8; 11–12	(5)	9.	1; 3; 5; 7; 9; 11	(11)	14.	1; 4; 7; 9–12	(9)
5.	2–5; 8; 10–11	(4)	10.	1–12	(1)	15.	2; 4; 6; 8; 10; 12	(12)

The apparatus was placed on a small table. Its operation was explained to *S*, in the following manner.

See this setting? (*E* pushes out Set 1, Problem I) and this set? (*E* presents Set 2), and this one (Set 3)? In each set there is a key, which on being pressed down, sounds a buzzer. This key is the correct key for that particular set, and, of course, in any given set there is but one key which will sound the buzzer. Now in all of these settings, and I have more, there is a common factor which determines which will be the correct key. In other words, you can work out a rule which will tell you which key will be correct for any setting I may give you. Is this clear? (*E* repeats material of directions if necessary.)

Your task is to work out a rule in as few 'sets' as you possibly can. Push down whatever keys you wish, while you look for the correct key. Analyze the situation as you go along. Think aloud. Take your time. Do not rush. I shall give you as many sets as you want. Tell me when you are ready for a new one. As soon as you have a rule to offer, announce it at once, and I shall then give you some sets

to test it out. If your rule works, you have solved the problem. Remember to watch carefully for the critical factor determining which is the correct key for each set, and to think aloud.

These directions were repeated if necessary. After the completion of the first problem, *S* was given the additional instructions:

You have just solved one problem. Shall I reread your directions? Every problem will be presented in the same manner as the one you have just finished. Each, however, depends on a different factor for its solution. Do not forget that. Remember that it is important that you think aloud, and that you announce your solution to me just as soon as you can.

Beginning with Problem IV, the *S*s were allowed to use notes, but they were told that this privilege did not signifiy that the problems were getting more difficult but that they were merely allowed this aid as some *S*s had complained that "solving a problem was just a matter of a good memory." "Note taking" was to be construed merely as a convenience to the *S*, and to be done in any manner he desired, or not at all, if he so saw fit. The same directions given at the beginning still held.

The "thinking aloud" enabled *E* to keep in close touch with *S*'s progress. If *S* found it difficult or distracting, it was not insisted upon. The privilege of taking notes on the latter problems (Problems IV, V, and VI) makes the situation less artificial, and helps to eliminate the objection made by many *S*s during the preliminary experiments, viz. that solving the problems was a matter of memory.

(C) Experimental conditions. The experimental work was conducted in a quiet room. Preliminary work with 20 *S*s was done during the school year 1928-1929. The results of these experiments are not included, however, in this report. The results here reported were obtained during the years 1929-1931 from 60 *S*s, of whom 49 were undergraduate students, 6 graduate students *(KS, JC, TR, MeB, AG, MP)*, 2 members of the staff *(EMT, MM)*, 2 young school teachers *(IK, LG)*, and 1 commercial student *(CS)*. The sexes were equally divided. The ages of the *S*s varied from 16-30 yr.; most (50), however, being between 17-22 yr. All were naïve, at the outset of the experiment, in this kind of work.

As has been indicated, there were two card periods, each separated by intervals of approximately 48 hr. The average time necessary for the solution of the problems was roughly 2 hr. In view of fatigue, the *S*s were not allowed to work more than an hour at a time. Because of individual differences in the rate of working, no rigid rule could be followed regarding the number of multiple choice problems to be completed in one experimental sitting. In general, however, Problems I, II, III, and IV were solved in the first sitting, and V and VI in the last.

(D) Method of scoring. (1) Cards. Correct cards were counted until more than three successive errors were made. Errors were of name, suite, and omission.

(2) Multiple choice. Scoring was done in terms of the number of 'sets' necessary until an adequate solution was formulated.[10] The scores represent the difference between this value and the number of sets necessary to illustrate the problem.

[10] The number of 'sets' has been used rather than the number of 'errors' (moves): (1) because of the emphasis on the set as a situation; and (2) because of the complications in Problem IV, where on the basis of 'errors,' an *S* going through 40 sets might receive a better score than another *S* who experimented with various keys finally getting the problem in 20 sets.

TABLE II

RAW SCORES FOR the DIFFERENT Ss in the DIFFERENT PROBLEMS

S	Multiple Choice						Cards	
	I	II	III	IV	V	VI	1	2
MM	1	1	1	3	2	2	17	31
IK	0	1	2	4	4	2	15	34
RA	1	1	1	7	8	23	20	30
KS	2	1	2	4	1	NC	12	10
HF	1	1	7	3	9	19	6	9
EMT	1	1	1	37	1	3	11	14
FR	3	1	2	7	23	23	11	16
JO	1	1	1	9	37	3	11	29
LL	3	1	2	26	28	14	21	30
CF	1	2	2	38	0	NC	8	12
MeB	0	0	4	25	NC	4	11	14
BZ	1	1	11	29	10	35	18	31
BC	1	16	3	23	26	9	14	24
Le	1	1	8	45	39	3	24	35
LS	1	1	4	DNC	19	5	27	35
RN	1	1	4	DNC	30	3	19	38
ML	1	DNC	4	DNC	38	31	12	32
LA	1	1	4	7	9	DNC	12	14
ET	1	2	3	17	2	DNC	13	33
ES	2	1	8	4	15	DNC	7	15
FG	2	1	4	3	27	DNC	15	28
AG	1	1	1	43	1	DNC	12	9
RP	5	0	1	11	39	DNC	17	29
IB	0	2	1	8	39	DNC	13	37
ErB	4	2	3	29	27	DNC	10	18
RC	1	13	3	23	NC	DNC	6	10
BS	1	10	2	DNC	DNC	1	13	13
SF	1	DNC	DNC	3	DNC	4	8	13
JR	2	1	DNC	DNC	DNC	40	13	27
NR	3	2	13	DNC	24	DNC	4	5
AF	1	1	2	DNC	NC	DNC	12	28
DR	1	2	6	DNC	NC	DNC	11	14
EK	1	5	19	DNC	NC	DNC	15	10
MP	1	1	2	1	DNC	DNC	16	20
HH	3	2	2	5	DNC	DNC	14	19
JS	1	2	5	1	DNC	DNC	11	16
LG	1	2	3	14	DNC	DNC	12	16
TR	1	3	3	15	DNC	DNC	22	32
VK	1	1	7	15	DNC	DNC	15	17
WL	1	2	13	10	DNC	DNC	16	21
SJ	1	1	2	38	DNC	DNC	16	18
SS	2	15	10	6	DNC	DNC	20	32
EJ	6	3	19	15	DNC	DNC	7	11
BK	2	1	DNC	DNC	7	DNC	12	15
EmB	1	1	DNC	DNC	9	DNC	8	18
AW	5	1	DNC	DNC	21	DNC	22	29
DB	6	DNC	11	38	DNC	DNC	18	24
SG	2	1	DNC	32	DNC	DNC	9	15
RH	1	0	1	DNC	DNC	DNC	11	18
CL	1	1	1	DNC	DNC	DNC	26	49
EL	1	0	5	DNC	DNC	DNC	7	15
SK	6	2	3	DNC	DNC	DNC	7	11
EdL	1	7	7	DNC	DNC	DNC	16	29
PJ	1	1	18	DNC	DNC	DNC	25	37
CS	1	14	4	DNC	DNC	DNC	4	9
MaB	1	9	10	DNC	DNC	DNC	15	15
EF	1	DNC	4	DNC	DNC	DNC	9	17
GK	2	2	DNC	DNC	DNC	DNC	11	17
AC	3	2	DNC	DNC	DNC	DNC	9	15
LR	2	18	DNC	DNC	DNC	DNC	13	16
Mean	1.70	2.98	5.08	16.6	14.9	12.5	13.5	21.3

These subtraction values are as follows: Problem I, 1; II, 2; III, 1; IV, 2; V, 2; and VI, 5.

Unknown to *S*, the number of sets to be given for each problem was limited: Problems I, II, and III to 20 sets; and Problems IV, V, and VI to 45 sets. After the allotted number of sets had been used by an *S* (without resulting solution), he

was given a DNC unless his "thinking aloud" seemed to indicate that a solution was near. In this event, he was given several more sets (usually 10). In all cases but one *(Le)* these extra sets did not result in a solution. The actual solutions were divulged indirectly to *Ss* receiving DNC by means of pointers, and special sets, in such a way that they would think themselves responsible for most of the solution.

NC represents an adequate but inferior solution. These will be discussed later in greater detail.

(E) Method of treating results. (1) Cards. Inasmuch as Period 1 with the cards may be considered a period of practice in method for the *S*, the results for Period 2 alone have been used. This second period is complicated by the inclusion of a row of Hearts (A, 8, Q, 6) in the center of the deck, to serve as an objective and incentive. Scores, therefore, have been ranked.

(2) Multiple choice. The problem of DNC and NC has been attacked in two ways. For intercorrelations, for which the results of individual problems are used, scores have been given rank orders. DNC and NC, hence, receive the median rank of their group. At best this method is somewhat gross, as can be seen from the fact that an *S* with a score of two receives a rank of 39, and a rank of 18.5 for a score of one (Problem II). The results of Problem I have not been used for the reason that they show but little scatter, and hence, have low value as a comparatively sensitive measure of individual differences. Moreover, Problem I serves as an introductory problem. Obviously, these individual problem rankings are inadequate for combination into battery form, for all or any portion of the total number of problems. Further difficulty is encountered in using these individual ranks in dealing with the problem of DNC. A DNC for Problem III receives a rank of 56, for Problem VI, a rank of 40.5. It is thus possible for an *S* to receive a 'worse' total ranking by missing an 'easier' problem and solving the latter problems, than by completing the earlier problems and not completing the latter ones.

It therefore becomes necessary to use some method of weighting based upon some criterion of difficulty, in handling these DNC. The use of the mean does not seem feasible with these data. An inspection of the means for each problem reveals that the mean reaches a peak in Problem IV, and then diminishes, whereas the number of DNC does not keep pace. The following shows this in unambiguous terms:

Problem	I	II	III	IV	V	VI
Mean	1.70	2.98	5.08	16.6	14.9	12.5
No. DNC	0	4	9	24	27	40

The number of DNC for Problem VI is almost double that for Problem IV, although the mean for Problem VI is much lower. In this connection, it should be stated that DNC and NC do not enter into the computation of these means. The means for the latter problems are based on fewer cases as a consequence.

The criterion of difficulty chosen was the number of *Ss* completing the given problem. With 56 as a base (Problem II), the weighting indices are as follows:

Problem	II	III	IV	V	VI
Weighting Index	1.000	1.098	1.555	1.697	2.800
Reciprocal	1.0000	.9107	.6429	.5893	.3571

Treating the scores now becomes a matter of evaluating *S*'s performance on the basis of (a) the problems completed, and (b) the score obtained in them. On

the basis of (a) an *S*'s performance will fall into one of 15 groups on the basis of summation of weighting indices for those problems he completes. Thus an *S* completing all the problems will fall in the first ranking group (Table III) with a summative ranking index of 8.15. The position of this *S* within the group will depend upon his performance in the individual problems (b). These scores, in

TABLE III

SUMMATIVE RANKING INDICES IN TERMS OF PROBLEMS COMPLETED

Problem						Battery	
II	III	IV	V	VI	f	A	B
					14	5.350	8.150
		+			2	3.795	6.595
+		+			1	2.795	5.595
				+	9	5.350	5.350
		+	+		1	2.098	4.898
+	+		+		1	1.555	4.355
	+	+	+		1	1.000	3.800
		+		+	4	3.795	3.795
			+	+	10	3.653	3.653
	+	+		+	3	2.697	2.697
+			+	+	1	2.653	2.653
	+		+	+	1	2.555	2.555
		+	+	+	8	2.098	2.098
+		+	+	+	1	1.098	1.098
	+	+	+	+	3	1.000	1.000

terms of sets, are equated by the use of the reciprocal of the individual problem indices, and summed. By means of these two steps it is possible to rank the *S*s in a very clearly differentiated manner. In only one instance do 2 *S*s receive the same ranking (*GK* and *AC*).

Table III gives the summative ranking indices and *S* frequencies in terms of problems completed. Blank spaces indicate that the problem was solved; plus signs represent DNC. For reasons given earlier, the results for Problem I are not used. Because of the large number of DNC for Problem VI, the summative ranking indices are given for two batteries—A and B. Battery A includes Problems II, III, IV, V; and B, Problems II, III, IV, V, and VI.

TABLE IV

DNC DISTRIBUTION IN PROBLEMS

Problems	II	III	IV	V	VI
II	(4)				
III	1	(9)			
IV	2	7	(24)		
V	3	6	14	(27)	
VI	2	7	19	24	(40)

The distribution of the DNC for the various problems is given in Table IV. The parenthetical number represents the total number of DNC for the corresponding problem number listed at the head (and side) of the column. The distribution is given by the other values listed, for example (line 2 of table): of the four *S*s receiving DNC in Problem II, one did not complete Problem III,

TABLE V

RANKINGS FOR THE DIFFERENT Ss IN THE DIFFERENT PROBLEMS

	Multiple Choice						Battery		Cards
S	I	II	III	IV	V	VI	A	B	2
MM	22.0	18.5	5.0	4.5	5.5	2.5	1.0	1.0	12.5
IK	2.0	18.5	14.5	8.0	7.0	2.5	3.0	2.0	7.0
RA	22.0	18.5	5.0	13.0	9.0	14.5	4.0	3.0	14.5
KS	45.0	18.5	14.5	8.0	3.0	19.5	2.0	4.0	55.0
HF	22.0	18.5	39.0	4.5	11.0	13.0	6.0	5.0	58.0
EMT	22.0	18.5	5.0	31.0	3.0	5.5	11.0	6.0	46.5
FR	52.0	18.5	14.5	13.0	17.0	14.5	9.0	7.0	36.5
JO	22.0	18.5	5.0	16.0	24.0	5.5	13.0	8.0	17.5
LL	52.0	18.5	14.5	27.0	22.0	12.0	18.0	9.0	14.5
CF	22.0	39.0	14.5	33.0	1.0	19.5	12.0	10.0	51.0
MeB	2.0	2.5	30.5	26.0	31.0	8.5	20.0	11.0	46.5
BZ	22.0	18.5	45.5	28.5	13.0	17.0	17.0	12.0	12.5
BC	22.0	55.0	23.0	24.5	19.0	11.0	21.0	13.0	23.5
Le	22.0	18.5	41.5	36.0	27.0	5.5	23.0	14.0	5.5
LS	22.0	18.5	30.5	48.5	15.0	10.0	26.0	15.0	5.5
RN	22.0	18.5	30.5	48.5	23.0	5.5	28.0	16.0	2.0
ML	22.0	58.5	30.5	48.5	25.0	16.0	40.0	17.0	10.0
LA	22.0	18.5	30.5	13.0	11.0	40.5	5.0	18.0	46.5
ET	22.0	39.0	23.0	23.0	5.5	40.5	7.0	19.0	8.0
ES	45.0	18.5	41.5	8.0	14.0	40.5	8.0	20.0	41.5
FG	45.0	18.5	30.5	4.5	20.5	40.5	10.0	21.0	20.5
AG	22.0	18.5	5.0	35.0	3.0	40.5	14.0	22.0	58.0
RP	56.5	2.5	5.0	18.0	27.0	40.5	15.0	23.0	17.5
IB	2.0	39.0	5.0	15.0	27.0	40.5	16.0	24.0	3.5
ErB	55.0	39.0	23.0	28.5	20.5	80.5	19.0	25.0	29.5
RC	22.0	52.0	23.0	24.5	31.0	40.5	22.0	26.0	55.0
BS	22.0	51.0	14.5	48.5	47.0	41.0	50.0	27.0	49.5
SP	22.0	58.5	56.0	4.5	47.0	8.5	55.0	28.0	49.5
JR	45.0	18.5	56.0	48.5	47.0	8.0	57.0	29.0	22.0
NR	52.0	39.0	47.5	48.5	18.0	10.5	29.0	30.0	60.0
AF	22.0	18.5	14.5	48.5	31.0	40.5	24.5	31.0	20.5
DR	22.0	39.0	37.0	48.5	31.0	40.5	27.0	32.0	46.5
EK	22.0	48.0	50.5	48.5	31.0	40.5	20.0	33.0	55.0
MP	22.0	18.5	14.5	1.5	47.0	40.5	30.0	34.0	26.0
HH	52.0	39.0	14.5	10.0	47.0	40.5	31.0	35.0	27.0
JS	22.0	39.0	35.5	1.5	47.0	40.5	32.0	36.0	36.5
LG	22.0	39.0	23.0	19.0	47.0	40.5	33.0	37.0	36.5
TR	22.0	46.5	23.0	20.5	47.0	40.5	34.0	38.0	10.0
VK	22.0	18.5	39.0	20.5	47.0	40.5	35.0	39.0	33.0
WL	22.0	39.0	47.5	17.0	47.0	40.5	36.0	40.0	25.0
SJ	22.0	18.5	14.5	33.0	47.0	40.5	37.0	41.0	29.5
SS	45.0	54.0	43.5	11.0	47.0	40.5	38.0	42.0	10.0
EJ	59.0	46.5	50.5	22.0	47.0	40.5	39.0	43.0	52.0
BK	45.0	18.5	56.0	48.5	8.0	40.5	41.0	44.0	41.5
EmB	22.0	18.5	56.0	48.5	11.0	40.5	42.0	45.0	29.5
AW	56.5	18.5	56.0	48.5	16.0	40.5	43.0	46.0	17.5
DB	59.0	58.5	45.5	33.0	47.0	40.5	44.0	47.0	23.5
SG	45.0	18.5	56.0	30.0	47.0	40.5	45.0	48.0	41.5
RH	22.0	2.5	5.0	48.5	47.0	40.5	46.0	49.0	29.5
CL	22.0	18.5	5.0	48.5	47.0	40.5	47.0	50.0	1.0
EL	22.0	2.5	35.5	48.5	47.0	40.5	48.0	51.0	31.5
SK	59.0	39.0	23.0	48.5	47.0	40.5	49.0	52.0	52.5
EdL	22.0	49 0	39.0	48.5	47.0	40.5	51.0	53.0	17.5
PJ	22.0	18.5	49.0	48.5	47.0	40.5	52.0	54.0	3.5
CS	22.0	53.0	30.5	48.5	47.0	40.5	53.0	55.0	58.0
MaB	22.0	50.0	43.5	48.5	47.0	40.5	54.0	56.0	41.5
EF	22.0	58.5	30.5	48.5	47.0	40.5	56.0	57.0	33.0
CK	45.0	39.0	56.0	48.5	47.0	40.5	58.5	58.5	33.0
AG	52.0	39.0	56.0	48.5	47.0	40.5	58.5	58.5	41.5
LR	45.0	56.0	56.0	48.5	47.0	40.5	60.0	60.0	36.5

two did not complete Problem IV, three did not complete Problem V, and two did not complete Problem VI. It will be noted that in all cases but two, there is an increase in the number of DNC as we go from the easier to the more difficult problems. This, too, is in accord with our criterion. The two inversions are minimal.

In Table V will be found the raw data converted to ranks. This method of combining the scores has several advantages. The weighting index is not arbi-

trarily fixed, but varies directly with the actual results. One may consider 56 points to be available for each problem solved, the number of *Ss* solving a given problem determining the 'credit' to be given each *S* for that problem. The number of *Ss* solving a given problem will vary with the number of DNC for that problem. Yet, it will not be necessary to deal directly with the DNC in treating the data, either by way of assigning arbitrary scores to them, using a method of ranking, or percentiling. In addition, our method can be used conveniently to combine any problems in the battery, so that one need not depend on the efficacy of partials in working out the effect of each problem on the battery. A further advantage of this method is that within each ranking group, an *S* is compared only with other *Ss* who have successfully completed the same problems as he.

NC have been regarded as successful solutions, in determining the summative rank index of the *S* under consideration. In computing the *S*'s rank within the rank group, NC were given the maximum number of sets possible for that problem. As has been stated earlier, these NC cases represent an adequate but 'inferior' solution. For example, one *S* (*EK*) formulated the following as the solution of Problem V: "When there are 3 keys, it's the first; 5 keys, the second; 7 keys, the third; 9 keys, the fourth; 11 keys, the fifth. Each time you count from the opposite side that you counted from before." The solutions offered by the other 4 NC for this problem are similar to *EK*'s. Two *NC* will be found for Problem VI (*KS* and *CF*). In both instances a solution was offered, "when there's 1 group, it's the first key; 2 groups, the second key." Nothing was offered for 3 and 4 groups, although the correct key was found in every instance without error. The NC total 7 in number and fall in Problems V and VI only.

The question arises—can these final scores in terms of rank, be regarded as scores? Strictly speaking, the answer is no. The most telling criticism of ranking is that differences in rank and in score are not commensurate. Our data, however, reveals comparative continuity both in respect to differences in the same summative rank group, and differences between groups. In any given group the differences from *S* to *S*, for the highest part, are both clean cut and comparatively regular. The differences from group to group are not great when considered in terms of the frequencies of *Ss* falling into the various groups. It seems to the writer that the limitations usually imposed by a method of ranking are at a minimum in his treatment, and that in a looser sense, although a comparatively accurate one, these ranks may be construed as scores.

The foundation of our method of treating the multiple choice results is the criterion chosen for difficulty. A consequence of this criterion is that an *S*'s rank is determined primarily by the problems he completes, and only secondarily by his proficiency (in terms of sets necessary for solution) in these problems. As a result, no matter how well an *S* may acquit himself in the problems he solves, a second *S*—who may require the maximum number of sets, but who on the other hand solves either more problems or an equal number of greater "weight"—will receive a higher rank than the first. This consideration presents a great difficulty to any plan for converting the *S*'s complete performance to score form. We have tried several other methods of treating the results, but have been unable to overcome this difficulty without losing the advantages gained by this ranking technique. Among these other methods have been: (a) using the total number of sets possible, as a base for weighting indices (the proportionality of each index to the

others is not changed), adding the reciprocals to the summed equated values of individual problem scores; (b) using a value derived by dividing the total number of sets possible by the summative rank index, and adding the equated scores to this value as a base; and (c) adding the maximum number of sets for each problem not solved to the *S*'s summed equated scores. All these methods gave scores to some *S*s which were at variance with his criterion of difficulty. Using larger although still proportional (with reference to the criterion) gaps between ranking groups, introduces factors not dependent on the data themselves. An artificial discontinuity is introduced between *S*s falling in one group and *S*s falling into an adjacent group. It should be remembered that these groups consist of *S*s who have solved the same problems. These groups may be considered as the 15 performance patterns made by the *S*s in solving the problems. These 'patterns' are in no way dependent upon any criteria of difficulty.

It seems reasonable to assume that the data has continuity, and that the continuity between groups (obtained by our ranking procedure) is more nearly adequate than the discontinuity between groups attendant on the introduction of a "gap" arbitrarily made large enough to prevent overlapping between groups, as is necessary in accordance with our criterion.

Results

(1) *Cards.* An examination of the gross results (Table II) indicates an average improvement of 57.8% for Period 2 over Period 1, with an S.D. of 2.68 for Period 1, and 4.74 for Period 2. All *S*s but 5 (*KS, AG, BS, EK, MaB*) improved in the second period. Of these *S*s, 3 showed losses. Improvement in the remaining 55 *S*s varies from 1-24 cards. The average improvement for all cases is 7.8 cards. In terms of the standard errors of the means, the reliability of the difference is expressed by $7.8 \pm .703$. Period 2 correlates $0.777 \pm .034$ with Period 1 (product-moment).

The method seems adequate to our purpose. The range is large, much larger than with most 'learning methods' currently used. It did not prove necessary to teach the names of the cards to any *S*. The conditions imposed upon *S* in learning the cards, lessen the artificiality of the laboratory conditions usually imposed. The conditions more nearly approximate those of his everyday learnings in that the *S* is free to set his own pace.

(2) *Multiple choice.* In view of the diversity of 'principles' in the various problems, it will be interesting to work out the intercorrelations of problems of the battery. These values will be found in Table VI. Individual problem rankings have been used in the computations. The limitations of these values have been discussed above on page 423. These correlations are, therefore, somewhat gross and give us little more than trends.

How valuable is each problem to the battery? We have gone about answering this question in two ways: (a) the correlation of each problem

TABLE VI

Intercorrelations of Problems

Problems	II	III	IV	V
III	.33 ± .078			
IV	.20 ± .084	.34 ± .077		
V	.44 ± .070	.34 ± .077	.30 ± .079	
VI	.37 ± .075	.39 ± .074	.35 ± .076	.55 ± .061

with the battery; (b) the effect on the battery when the individual problem is omitted.

(a) The correlation of each problem with the battery,[11] both when A and B are used, is given in Table VII.

(b) With the method of battery combination outlined above (p. 424), it is possible to combine any of the problems used. Hence, we can correlate a battery consisting of Problems III, IV, V, VI, with a battery consisting of Problems II, III, IV, V, VI; a battery of Problems III, IV, V with II, III, IV, V and find the effect of Problem II, and so on. These values are given in Table VIII. Battery A consists of Problems II, III, IV, V; and B, of Problems II, III, IV, V, VI. Parentheses indicate omission, hence (II) under A designates that this correlation value is of Problems III, IV, V with a battery consisting of Problems, II, III, IV, V, and so on.

TABLE VII

Correlations of Each Problem with Batteries

Problem	Battery	
	A	B
II	.45 ± .069	.39 ± .074
III	.57 ± .059	.53 ± .063
IV	.65 ± .050	.56 ± .060
V	.81 ± .030	.78 ± .034
VI	.48 ± .067	.78 ± .034

TABLE VIII

Correlations to Show the Effect of Problem on Battery when Problem in Question Is Omitted

Problem omitted	Battery	
	A	B
(II)	.99 ± .002	.99 ± .002
(III)	.96 ± .007	.97 ± .005
(IV)	.92 ± .013	.94 ± .010
(V)	.79 ± .033	.90 ± .017
(VI)		.87 ± .021

[11] All correlations, except as otherwise stated, have been done by the method of Rank Differences: $\varrho = 1 - 6\Sigma(R_x - R_y)^2/N(N^2 - 1)$; $r = 2\sin[(\pi/6)\varrho]$.

From Table VII it will be seen that, when the entire battery (B) is considered, Problems V and VI correlate rather highly and equally with the battery. Moreover, except in the case of Problem VI, the correlations in Batteries A and B vary but little. The greater difference in the case of Problem VI (0.48 and 0.78) may be due to the fact that the effect of Problem VI is not felt in Battery A. The scores of individual problems were taken care of by rankings, in the computations of these correlations.

In determining the effect of individual problems on the battery by means of (b) the procedure is somewhat indirect. When a particular problem is omitted from a battery, the greater the correlation with the complete battery, the less the effect (or disturbance) may be said to be due to this problem, and hence, the less the problem under consideration contributes to the battery. Table VIII clearly reveals that Problem II contributes least, and Problem VI the most (when Battery B is considered). The intermediate differences are not great, however. The equivalent values for Battery A vary but slightly from those for B, except in the instance of Problem V.

It would seem, from an inspection of Tables VII and VIII, that the battery of problems given the *S* might be reduced without suffering especially in efficacy. Some of the possible combinations of problems and their correlations with Batteries A and B are given in Table IX. The best combination for both batteries would seem to be a combination of III, IV and V; with IV and V almost as efficient. These combinations should be verified experimentally, since the results of our preliminary experiment give evidence that the "order of presentation" is a factor in their difficulty to the *S*.[12]

(3) *Correlations between cards and multiple choice problems.* The correlation between the results in card learning and Battery A is 0.08 $\pm$ .087, and between card learning and Battery B is 0.10 $\pm$ .086. The correlation between card learning and the different multiple choice problems is: Problem II, 0.23 $\pm$ .083; III, 0.19 $\pm$ .084; IV, 0.09 $\pm$ .086; V, 0.07 $\pm$ .087; and VI, 0.30 $\pm$ .079.

The correlations for the batteries are very low. The correlation of 0.30 of Problem VI with the cards, is based upon data in which 67% of the *S*s (40) receive the same ranking. It is curious that the correlations of individual problems are lowest for Problems IV and V whose results give

[12] See also W. Brown and F. Whittell, Yerkes' multiple choice method with human adults, *J. Comp. Psychol.*, 3, 1923, 305-318, esp. 315-316.

the greatest scatter. These correlations (.09 and .07) are virtually identical with the battery correlations (.08 and .10), although these two problems do not correlate to a commensurate extent with the two batteries (see Tables VII and VIII). The probable errors are all high, and further reduce the minimal significance of these correlations.

TABLE IX

Correlations of Various Problem Combinations with Batteries A and B

Problems	Battery	
	A	B
II, III, IV	.79 ± .033	.64 ± .051
II, III, V	.92 ± .013	.84 ± .026
II, IV, V	.96 ± .007	.87 ± .021
III, IV, V	.99 ± .002	.91 ± .015
IV, V, VI	.83 ± .027	.96 ± .007
IV, V	.94 ± .010	.89 ± .018

(4) *Sex differences.* (a) *Cards.* The data when classified according to sexes reveal an average of 24.4 correct cards for men, and 18.2 for women (Period 2). A proportionate difference is found when the results for Period 1 are considered: 15.5 correct cards for men and 11.1 for women.

(b) *Multiple choice.* These results when analyzed as to sexes, also give the men general superiority. In Table X are listed the average number of sets necessary for solution; the number of *S*s on which these averages are based—the number of *S*s successfully completing the respective problems; the number of DNC; and the number of NC. Neither DNC nor NC enters into the computation of these averages.

TABLE X

Sex Differences with Problems

	Problems									
	II		III		IV		V		VI	
	M	W	M	W	M	W	M	W	M	W
Av. no. sets	2.03	4.00	4.26	6.00	20.3	12.6	16.6	19.3	7.4	20.4
No. completing	29	27	27	24	19	17	18	10	11	7
No. of DNC	1	3	3	6	11	13	9	18	17	23
No. of NC	0	0	0	0	0	0	3	2	2	0

It will be noted that, with the exception of Problem IV, the men are definitely superior to the women both from a standpoint of the average number of sets, and the number of DNC. In the aggregate there are 41 DNC for men to 63 for women. In Problem IV alone, do the females prove superior to the males, although the DNC are almost equally distributed.

These sex differences may be considered to be summed up by the sex distribution in the batteries: In Battery B, of the first 30 ranks, 17 are occupied by men (av. 11.5), and 13 by women (av. 20.7). For the entire battery the average rank of the men is 26.17, and of the women, 34.83. The difference is even more marked in Battery A. Here, of the first 30 ranks 19 are occupied by men (av. 14.5), and 11 by women (av. 17.3). The average rank for this entire battery is 25.7 for men, and 35.7 for women.

The method of 'standard error' does not seem an adequate instrument in determining the reliability of the differences of the respective averages of men and women. Our experimental technique has placed a premium on scatter. The data, for the greatest part, show well distributed scores which do not fall into a distribution even analagous to a Gaussian distribution. Our statement of definite sex differences is based on three lines of evidence: (1) respective number of DNC for men and women (multiple choice); (2) the respective averages (multiple choice and cards); and (3) the rank distributions in the batteries and cards. The matter of the possibility of sampling error will be further discussed in a later paragraph.

In view of these sex differences it may be of advantage to correlate the cards with multiple choice, when the sexes are taken separately. These correlations have been computed by correlating the respective ranks of cards and multiple choice, by the product-moment method.

Sex	M	W
Battery A	—.175 ± .119	.181 ± .119
Battery B	—.123 ± .121	.275 ± .114

These correlations, while not high, are suggestive in spite of the high P.E. It will be remembered that Problem VI correlates highest of the individual problems with the cards; and that, of the 20 *Ss* completing this problem, 17 were men. We should expect, therefore, an accentuation of the r for the men, when Problem VI is omitted (Battery A). It is evident that such has been the case.

From these results on sex differences it seems highly possible that there may be present definite correlation trends between serial learning and generalizing abstraction when the sexes are treated separately. These trends will be obscured when the results are taken in the aggregate. Our results, however, are based on too few *Ss* to make a positive statement.

We have the following evidence to submit that these sex differences are *not* due to the sampling of *Ss* used in the investigation: (1) Sampling would not

account for the superiority of the women with Problem IV. (2) A sampling error seems incompatible with the negative correlation trend of Cards with Multiple Choice for men, and with the higher positive trend of correlation for women. (3) S.A.T. scores (College Entrance Board) for 42 of the 60 *Ss* (24 women and 18 men) give the 'usual' distribution of the sexes: men, av. 482.1; women, av. 479.3. This item, while not inclusive, seems indicative.

An examination of the nature of Problem IV may give us a few suggestions regarding the respective performance of men and women. In this problem, the principle is 'odd-even,' with the right end of the set as the point of reference. In solving this problem, most *Ss* went through these steps: (1) found point of reference, (2) attempted to work out a sequence to predict the appearance of the first and second keys as the correct key, (3) failing in this, changed method of attack. All DNC went through the first two steps listed. Except for those few *Ss* completing the problem within very few sets, much of the difference in scores may be accounted for in terms of the persistence of the sequence attitude, in spite of the contradictions given the *S* by his own data. There exist, consequently, the possibilities that the sex differences in the performance of this problem may be due to 'persistence' differences between the sexes, or, to a feminine aptitude for odd-even relationships.

Summary and Conclusions

A study was made of serial learning and generalizing abstraction, as revealed by the learning of the serial order of a deck of playing cards and the Yerkes multiple choice method respectively. The results on 60 *Ss* show:

(1) A non-significant, although positive correlation between serial learning results and generalizing abstraction results: $0.08 \pm .087$; $0.10 \pm .086$.

(2) Sex differences in both serial learning and generalizing abstraction. These differences do not seem entirely accountable for in terms of a sampling error.

(3) Correlations between serial learning and generalizing abstraction results, when the sexes are treated separately, are positive for women ($0.181 \pm .119$; $0.275 \pm .114$); and negative for men (-0.175 ± 119; $-0.123 \pm .121$). There are too few cases, and the P.E. are quite high. The values are greater, however, than those obtained when the results are taken irrespective of sex, and seem extremely suggestive.